

HF Radar Experiment of Martian Surface in Planet-B. T. Okada¹, T. Ono², and H. Oya^{2, 1}
Institute of Space and Astronautical Science, 3-1-1 Yoshino-dai, Sagami-hara, Kanagawa, 229 Japan.
okada@planeta.sci.isas.ac.jp, ² Faculty of Science, Tohoku Univ., Sendai 980-77 Japan.

HF radar echo experiment of martian surface layers will be performed by using "PWS (Plasma Wave and Sounder)" instrument onboard Planet-B satellite which will be launched in 1998 and arrived to Mars in 1999, following 2 years' observation period in high eccentric orbit. When "ALT" mode of the instrument is used near the perigee of Mars, which transmits 9MHz (= 33m in wavelength) HF radar, the detection of the echo profile will be applied for (i) global mapping of martian surface topography, (ii) regional variation of radar reflectance, (iii) surveying subsurface layers at specific sites, and (iv) exploring the ground water.

Introduction

The characteristics of planetary surfaces reflect the physical properties and chemical composition of surface materials and the temporal and regional variation of volcanic and meteorological activities, and may sometimes provide us key information to resolve the surface structure, composition, and environment of the earlier stages and the the history of crust and mantle evolution. Many earth-based observations and spacecrafts orbiting Mars have surveyed the martian surfaces and have found many characteristic features in various regions. For example, the Mars has numerous impact craters, valleys and channels that might show the evidence of water flows in the past, ridges and grabens resulted from tectonic activities, and the Polar Ice Caps, as well as the huge shield volcanoes. The martian surface can be divided into several geologic/geological-time units by the crater densities and the stratigraphy. The measurements of the topographic profiles and the physical properties with higher accuracy and better spatial resolution are desired, since 3-dimensional mapping of the martian surface is necessary for better understanding of the martian tectonics, morphology and geology. Recent discovery of evidence of past martian life in meteorite[1] appeals the importance to exploring lives and the places lives existed or still exist, i.e. exploring the groundwater relatively shallow depth below the surface.

The PWS/ALT experiment will transmit and receive HF radar of 33m wavelength and measure the topographic features and the radar reflectivities every 1km along-the-track from an orbit (the perigee is 150km height). The accuracy of ALT's altimetry (21m) is not so good as LIDARs, but much better than that of previous observations[2] and adequate enough to measure the martian global shape and large geologic features. ALT will have two other advantages. One is in its long wavelength as an altimeter and waves are little affected by surface scatterers such as rocks and boulders. Another is its very high transparency up to the underground basements of tens to hundreds meter deep and it implies the possibility to detect the subsurface structures or existence of groundwater with the suitable receiving system. An HF radar may become the new probe for future planetary explorations, though ALSE of Apollo 17 has once carried out[3]. Much improved system will be developed for SELENE mission to the Moon.

Electrical properties of martian surface layers

Radar echo intensities will have information on the surface physical properties such as the porosity of materials, the surface conditions, the amount of waters and metals, and maybe the subsurface structure. The electrical properties of the uppermost surface layers of Mars appear to be somewhat more variable than for the Moon, with dielectric constants ranging from 1.5 to 5[4]. Olhoeft and Strangway (1974)[5] discussed the electrical properties for the regolith layers in terms of water

under the martian meteorological conditions. Their results show that the mean surface temperature of 213K is low enough to deactivate any amount of water so far as electrical properties are concerned. They did note, however, that surface pressures and temperatures observed by Mariner 9 occasionally became high enough to allow liquid water, in which case the electrical properties of the martian surface could be drastically altered, even though this would be a highly local phenomenon. The presence of exposed rocks is very likely and would show the higher reflectivity than for the regolith surfaces. Indeed, high reflective regions are reported[6].

Numerical Study

The ALT will perform the HF radar echo experiments with a much longer wavelength than that of the previous observations, and the radar echoes has the information on the average electrical properties from the surface to a few 10m depth. The high transparency expected for the desiccated or unactive surface materials is also a matter of concern, since HF radar is estimated to penetrate into several 100m depth or more. So making new models of the martian surface layers is necessary to examine the feasibilities in advance. We chose some examples of the martian surface layers : regoliths, exposed rocks, basement rocks covered with thin regoliths, permafrosts, and so on. The electrical properties of those kinds of likely martian surfaces can be estimated. We have calculated the simplest case and assumed that reflection occurred at only the uppermost surface layers[7]. Then we introduced only two parameters, r and C , to represent the radar echo phenomena by using well-known Hagfors' equation[8], where r is the reflectivity of the "average" surface and C means the surface rms roughness of observed area. Current study takes into account the transparency of HF radar and the electromagnetic boundaries of subsurface region. With some conditions, subsurface boundaries up to 100m depth may be detected. For example, rocky basement covered with most porous regolith can be detected if the regolith thickness is less than 100m, implying the structure of stylth region[9] can be studied. Things are similar for exploring the liquid water. The martian groundwater can be found at the limited region such as icelake or excavated features where the groundwater flows away to the proximity of the surface.

With this experiment, the subsurface structure and existence of groundwater may be explored if they occur relatively shallow depth below the surface. In order to observe in the best conditions, further study will be necessary in detail.

Reference

- [1] McKay, D.S. et al. (1996): Science 273, 924-930.
- [2] e.g. Esposito, P.B. et al. (1992): Chap.7 in Mars (ed:Kieffer et al.), pp.209-248.
- [3] e.g. Phillips, R.J. et al. (1973) : Apollo 17 Preliminary Science Report, NASA SP-330, Chap.22
- [4] Pettengill, G.H. et al. (1973) : Icarus, 18, pp.22-28.
- [5] Olhoeft, G.R. and D.W. Strangway (1974) : Geophys. Res. Lett., 1, pp.141-143.
- [6] e.g. Harmon, J.K. and S.J. Ostro (1985) : Icarus, 62, pp.110-128.
- [7] Okada, T. et al. (1995): Proc. 28th ISAS Lunar Planet. Symp. 193-196.
- [8] Hagfors, T. (1970) : Radio Sci., 5, pp.189-227.
- [9] Muhleman, D.O. (1991): Science 253, 1508-1513.